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Looking for structure in all the wrong places: Ramsey sentences, multiple realizability, and structure[*].

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1. Introduction

Structuralism has a long and interesting history, emerging in the early part of the twentieth century as a way of accommodating the new physics of General Relativity and Quantum Mechanics, and then again, in the later part, as a response to certain anti-realist arguments in the philosophy of science. In particular, structural realism has recently been presented as a way of meeting the apparent challenge offered by the history of science: namely, that this history appears to be one of changing ontologies, hence the realist's belief in our current ontology is supposedly undermined. Putting it crudely, the structural realist responds by urging the realist to shift her focus from the ontology, understood as an ontology of *objects*, to the relevant theoretical *structure*, which, it is claimed, exhibits significant commonalities between theories.

According to Worrall's 'epistemic' form of this view (Epistemic Structural Realism, or ESR), all that we *know* of the world is its structure, as exemplified in our scientific theories, and the 'nature' of the underlying elements (physical objects) remains 'hidden' in some sense. Ladyman's 'ontic' formulation, on the other hand, hearkens back to the earlier form of structuralism and insists

[*] This work has its origins in discussions on structuralism with Joseph Melia and Juha Saatsi and we are immesnely grateful to them for all their feedback and encouragement. Versions of various parts were presented at the Research Workshop of the Division of History and Philosophy of Science here at the University of Leeds and we would like to acknowledge all the comments and suggestions of the participants. We would particularly like to acknowledge helpful discussions with Roger White on Wiitgenstein's early form of Ramseyfication which could not include here due to lack of space.

that all there *is* in the world is structure, removing any 'hidden' elements. Both forms offer suggestions for the most appropriate way of representing this structure: Ladyman has notably adopted the so-called 'semantic' or model theoretic approach, whereas Worrall, at least in his more recent work, has advocated the well-known view that the structure of scientific theories is represented by means of the theory's Ramsey sentence. Our aim in this paper is to explore this latter representation and we hope to indicate that it is more problematic than might initially be thought.

Let us remind ourselves what the process of forming the 'Ramsey sentence' of a theory involves[1]. Essentially one simply replaces the theoretical terms of a theory with variables bound by existential quantifiers, like so:

$$T(t_1,\ldots t_n, o_1,\ldots,o_m) \rightarrow (\exists x_1),\ldots. (\exists x_n)T(x_1 ,\ldots.x_n ; o_1, \ldots.o_m)$$

In the present work we shall be concerned with the inter-relationship between the representation of structure in terms of Ramsey sentences and the further aspect of epistemic structural realism that has to do with the idea that the 'natures' of the underlying objects are in some sense unknown to us.

Prima facie the adoption of the Ramsey sentence as the machinery for expressing the structural content of the theory seems to provide a rigorous response to the issue of representing the "hidden natures" as well. Being an existential generalization of the original theory, RS can be reasonably seen as describing a class of realizers far broader than the one realizing the original theory. In the event that the class of realizers of RS were constituted by more than one n-tuple of items RS would be multiply realized. Since the available empirical evidence for each n-tuple of realizers is the same there is no way to choose any member of the class over the others and as far as our empirical knowledge is concerned RS can always be *multiply realizable*. Multiple realizability, thus, seems a way to express rigorously the idea of the structure being *epistemically* independent from the entities whose *natures* we are not in the position to know. The issue of multiple

[1] This is typically referred to as 'Ramseyfication'.

realizability features prominently in the history of the Ramsey sentence. We shall investigate this aspect of Ramseyfication and its significance for ESR. As we shall discuss, Lewis, (Lewis 1970) used Ramseyfication in order to provide a definition of theoretical terms and argued that multiple realizability should not be admitted on realist grounds. Thus he introduced a technical modification of the Ramsey sentence in order to block multiple realizability, but then in a later contribution rediscovered it as the bedrock of a 'thesis of humility'. Carnap, on the other hand, welcomed multiple realizability as a tool to express the openness of scientific theories towards change following new empirical information and formally accommodated it through the use of Hilbert's ε-operator.

Thus multiple realizability must be investigated in relation to Ramseyfication because what we understand as remaining unavoidably hidden to our knowledge depends in this case on both factors. More precisely, different choices in the formulation of the sentence can lead to different conceptions of the structure and, therefore, of what a multiply realizable Ramsey sentence treats as inaccessible to our knowledge.

The original strategy formulated by Ramsey and developed by Carnap is based on the adoption of two languages: A fully interpreted *observable* one – or O-language – whose descriptive constants label items with which we are perceptually acquainted, and a theoretical one, partially interpreted via correspondence rules - or C-rules - coordinating theoretical postulates - or T-postulates - to sentences in the O-language. Assuming some viable distinction between theoretical and observable terms in the theory a structuralist would reasonably expects this approach to provide a sharp formulation for the idea that the structure corresponds with some theoretical content captured not by any single theoretical term but rather by their mutual relation. The multiple realizability stresses this aspect, conjoining it - as observed by Carnap - with a form of openness with respect to the growth of knowledge. Openness the structuralist welcome as part of her response to theory change. As we shall note, Hintikka's view on Ramseyfication in an explicitly declared, structuralist, perspective can also be seen in these terms. However, despite the clearly stated structural character of the position, this approach does not generate a viable form of realism.

Lewis's strategy, on the contrary, rejects the very idea of such a distinction between theoretical and observable. In this case, the terms replaced by variables are the ones whose understanding is problematic in the light of the scientific lexicon accepted at the moment in which the theory is formulated; thus the resulting sentence is still heavily loaded with theoretical content. Our concerns here have to do with the structuralist element of Lewis's approach. In particular, given his *thesis of Ramseyan humility*, multiple realizability can make sense of the idea of "hidden natures" but, as we shall indicate, it implies the rejection of the notion of law as natural necessity. This may be an acceptable cost to some structural realists but it is a metaphysical cost nonetheless.

In order to address these issues we will adopt the following approach. The first section will explore the approaches of Ramsey, Hintikka and Carnap. What these approaches have in common is the adoption of the Observable\Theoretical distinction. We shall see that they do not offer any help to the realist, whether structuralist or not. The second section explores the evolution of Lewis's account. In this picture we can find undeniable similarities with epistemic structural realism but it is no longer clear how to accommodate the epistemic independence of the structure from the entities. To conclude with a slogan, the Ramsey sentence seems to be too short a blanket for the epistemic structural realist: either it yields a position which is structuralist but not realist or a position which is realist but not structuralist.

Section I- Structures Without Realism

1. From the Very Beginning: Ramsey's Ramsey Sentence

As is now well known, Ramsey introduced his treatment of theoretical terms as existentially bound variables in his 1929 paper 'Theories' (Ramsey 1978, pp. 101-125). The relevant understanding of theories is a form of what has come to be called the 'Received View', according to which a theory is represented in terms of a set of axioms, from which various theorems can be deduced, and related to the propositions expressing the 'facts to be explained' by a 'dictionary', taking the form of a series of definitions understood as equivalences (ibid., pp. 103-104). In considering how one might explain the 'functioning' of theories in the absence of explicit definitions (within the system of facts)[2], Ramsey noted that a theory is 'simply a language' which clothes the judgments given by laws and consequences, and which we can then use without having to work out these laws and consequences. Hence,

> 'The best way to write our theory seems to be this (∃ α, β, γ): dictionary**.**axioms' (*ibid*., p. 120)

where the α, β, γ are the propositional functions in terms of which the axioms are expressed. He goes on to note that,

> 'Here it is evident that α, β, γ are to be taken purely extensionally. Their extensions may be filled with intensions or not, but this is irrelevant to what can be deduced in the primary system.' (*ibid*.)

Interestingly, Ramsey continues by insisting that any additions to a theory, whether these be new axioms or particular assertions, must be made within the scope of the original α, β, γ. Hence such additions are 'incomplete' in the sense that they are not strictly 'propositions by themselves' but only with respect to the theoretical context[3]. This implies that the *meaning* of such an addition can only be given when we know to what 'stock' of propositions it is to be added, and once that is determined the meaning is simply the difference between (∃α, β, γ): stock**.**addition and (**Ô**α, β, γ):

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[2] He previously argues that although we can always reproduce the structure of a theory by means of explicit definitions, such a construction cannot adequately accommodate the way in which theories are effectively 'open' to growth and further development (since within such a construction, adding a new axiom would require changing all the definitions and hence changing the meaning of the theory as a whole). This was a concern of Carnap's as well, and as we shall see, he responded in a particularly interesting manner.

[3] He gives the analogy with different sentences in a story beginning 'Once upon a time …'.

stock (*ibid.*, p. 120). Furthermore, since the addition is not a 'genuine' proposition, its truth can only be determined in the context of what else might be added to the stock and whether the addition concerned would 'suit' these further additions better than an alternative.

With the appropriation of the Ramsey sentence by realists there has been renewed interest in how Ramsey's work looks from a modern perspective. Of course, situating this work within the current realism-antirealism debate is tricky, as the terms of this debate are not straightforwardly applicable. Psillos rightly rejects as too quick the suggestion that Ramsey's position is close to phenomenalism (2000 p. 276 fn. 6). Certainly if this purported 'phenomenalism' is cashed out in terms of theoretical propositions being regarded as ultimately meaningless, then Ramsey himself rejects such an understanding (Ramsey op. cit.., pp. 122-123). As he makes clear at the very beginning, the aim of the paper is not to establish whether a theory *is* only a language for discussing facts, but to consider what sort of language it would be, if it were one. Psillos himself reads Ramsey in what appears to be a near-realist manner: a Ramsey sentence is, after all, truth-apt in that it implies the existence of classes of entities that realise it, even though it makes no commitment to the existence of a particular set of such entities (Psillos op. cit., p. 261). However, the mere truth-aptness of sentences has little if anything to offer to the realist, since certain kinds of anti-realist (van Fraassen for example) would happily agree with that. Furthermore, its capacity for delivering empirical knowledge does not depend on the truth of the original theory and its commitment is different from that of the latter. If Steven, Joe and Juha are in a room the claim "There is a bald male in the room with Juha" is true but it can be the existential generalization of both "Angelo is the bald male in the room with Juha" and "Joe is the bald male in the room with Juha"; only one of the original claims is true but the existential claim is true in both cases. Indeed, this is the nub of the problem: if the structural realist were to represent her ontological commitment to structure via Ramsey sentences, then her position is in danger of sailing too close to forms of anti-realism.

Furthermore, the use of the Ramsey sentence by the structural realist in particular has come under attack because of the so-called 'Newman problem'. As in the case of the sentence itself, this is an old issue, originally presented as an argument against Russell's form of structuralism and now dressed up in modern clothes (it has been revived through the work of Demopolous and Friedman 1995; for a recent discussion, see, for example, Psillos 1999, pp. 63-65). The basic idea is as follows: if we know only the *structure* of the world, then we actually know very little indeed. The central point is a straightforward formal one: '… given any 'aggregate' A, a system of relations between its members can be found having any assigned structure compatible with the cardinal number of A.' (Newman 1928, p. 140). Hence, the statement 'there exists a system of relations, defined over A, which has the assigned structure' yields information only about the cardinality of A:

'… the doctrine that *only* structure is known involves the doctrine that *nothing* can be known that is not logically deducible from the mere fact of existence, except ("theoretically") the number of constituting objects.' (*ibid*., p. 144; his emphasis).

The application of this argument to the structure given by science is straightforward: for any given aggregate, a variety of systems of physical relations is possible, yielding the required structure and the problem is how to justify the choice of one such system. One might try to pick out a particular system as physically 'important', in some sense, but then as Newman himself points out, either the notion of 'importance' is taken as primitive, which seems absurd, or it must be grounded on what Russell calls the 'intrinsic characters' of the relata, which undermines the very structuralism being defended (Newman *op. cit*., pp. 146-147; for a reprise of this point see Psillos *op. cit*.).

In its modern guise, the problem impacts directly on the structural realist who uses the representational resources of the Ramsey sentence, because if all the non-logical predicates of a theory are Ramseyfied out, then the resulting Ramsey sentence is true, if and only if the theory has a model; but this is trivial. Now there are two things one can say about this: first of all, the structural realist will insist that she has no intention of Ramseyfying out *all* the predicates of the theory, only the theoretical ones. Even then, it has been claimed, if the Ramsey sentence makes only true empirical predictions (and gets the cardinality of the domain right) then it will be true (Ketland 2004). However, it turns out that this is too quick and that the relevant proof relies on assumptions that the structural realist is under no obligation to accept (Melia and Saatsi forthcoming). We shall not pursue this here, as our concern is that even prior to addressing the Newman problem, the epistemic strucutral realist has problems with her choice of how to represent the structure she is interested in.

Secondly, however, even if all the terms, theoretical and observable, are replaced with existentially quantified variables, it might be argued that what this yields is still worth considering. This is the line Hinitkka takes in his suggestion that the relevant structure is now effectively represented by the relationships between the second-order quantifiers and these can be revealed by adopting his 'independence friendly' logic. We shall consider this here because of the connection bewteen this formal framework and Carnap's work, as exemplified by the role of 'choice functions'.

2. Hintikka's Independence Friendly Logic: a framework for structuralism?

Although he adopts a different approach from Ramsey, Hintikka's work can also be understood as contributing to the debate over structuralism and how to represent structure. In fact the notion of structure is clearly framed in model-theoretic terms: structures are conceived as family of models, and theories are seen as claiming that certain structures are instantiated at some point in the world. Hintikka interest in the Ramsey sentence (RS) and thus the relevance of his contribution to the debate on structural realism are closely entwined with his views on the theory of quantification. It is this which lies behind the most original aspect of his position: the use of the expressive resources of Independence friendly(IF)-logic to formulate RS.

Hintikka's general thesis can be summarized as follows:

1. The interaction between quantifiers can introduce theoretical concepts

2. Theoretical concepts indirectly frame the empirical content of the theory by constraining the number of models in which the empirical content is embeddable.
3. The best logical framework for representing the gist of quantification is *independence friendly* (IF) logic.
4. Ramsey sentences do not effect any elimination of theoretical concepts. They still fix via the interaction between quantifiers the structures in which the empirical content of theory is embeddable.
5. IF-logic is the natural framework in which to formulate Ramsey-sentences and thus to represent structures.

Our aim here is to clarify 1 and thus indicate the plausibility of 3. We shall then show that even assuming 2, 4 is still undermined by the Newman problem and thus 5 remains open to debate.

Before starting our analysis we need to be clear on which kind of Ramsey sentence we are dealing with. Hintikka invites us to consider a 'super-Ramsey' sentence, obtained by eliminating *all* terms, *T*- and *O*-, and replacing them with existentially quantified variables[4]. This can be taken to be trivial since all it says is that a structure of a certain kind can be (extensionally) defined on the relevant domain of individuals. The only condition such sentences impose is a restriction on the cardinality of the domain (basically the Newman result). Of course the ordinary Ramsey sentence has the same observational consequences as the original theory and hence is not trivial (see Worrall 1989; Ketland 2004; Melia and Saatsi forthcoming). Nevertheless, super-Ramsey sentences are interesting in that they state that structures of a certain kind are realized in the world, and – according to Hintikka – these structures can be complex and interesting, even though they are described without any predicates at all.

[4] J. Hintikka, 'Ramsey Sentences and the Meaning of Quantifiers', *Philosophy of Science* **65** (1998), pp. 289-305.

How can that be? The answer is that super-Ramsey sentences still contain predicate variables of course, so in effect the second-order quantifiers have taken up the ontological load: 'It is the second-order existential quantifiers that bring in the theoretical concepts.' (*op. cit.*., p. 297).

What concepts can be brought in, by this procedure? After all there is nothing to specify which are the sets of values that are supposed to substitute the variables appearing in the sentence. It seems we are just saying that "given something in relation to something, there is something else in some other relation to some further thing". Clarifying this point will involve an excursion into Hinitkka's views about quantification and will address our first point above.

It will be helpful to consider the following example:

(1) Every cat of the Colosseum has got a Roman citizen that feeds it.

In terms of first- order logic, (1) looks like

$$\forall x\ \exists y((C(x)\ \&\ R(y)) \Rightarrow (yFx)),\ (1.1.)$$

(1) is in other terms of the type $\forall x \exists y \varphi(x,y)$. (2)

Now establishing if (1) is true can be represented as a game[5]: when Player one comes with a cat Player two has to provide the corresponding Roman feeder. If the Roman feeder can always be produced, (1) is true. Formally – for instance in our 1.1 version – Player One is represented by $\forall$ whereas $\exists$ represents Player Two[6]. Now notice that the claim that (1) is true in our metaphoric game amounts to saying that there is a *strategy* that allowing the player $\exists$ to win the game. Put in a more formal way there is a function **f** that associates with any occurrence of x an **f**(x) such that the sentence (1.1.) is true.

In other and more general terms, we are claiming that

$$\forall x \exists y\ \varphi(x,y) \Leftrightarrow \exists \mathbf{f}\ \forall x\ \varphi(x, \mathbf{f}(x))\quad (I)$$

[5] It is important to observe here that game-theoretical notions are crucial within the architecture of Hintikka's logical theory. See for instance Hintikka 1996, 1997, 2000. For the sake of our analysis this can be seen as a useful and natural clarifying expedient.

[6]See Gabbay and Guenthner (Eds) *Handbook of Philosophical Logic* Kluwer, Boston, 2001,p 86 . There Hodges presents Skolem functions in a game-like setting.

The equivalence expressed by (I) allows one to bring all first order sentences into the so called Skolem normal form.

The function **f** is the Skolem function associated with the sentence (2) and the metaphor of the game helps to clarify the point that it is the interplay between the quantifiers that introduces it. In other terms such an interplay corresponds to the introduction of a specific *concept*. Or, in other words, what we would call a concept (theoretical or not) in the debate about theories since it appears in the sentence with the same syntactical characteristics and we are explicitly adopting a purely extensional perspective. This appears to be what Hintikka. has in mind when he says:

'If quantifiers are construed as higher-order predicates or if they are thought to receive their meaning by "ranging over" a range of values or to receive it from the totality of their substitution-values, the kind of interplay of different quantifiers with each other that is codified by their associated Skolem functions remains unexplained.' (*ibid*., p. 304).

Observe that sentences like $\exists \mathbf{f}\ \forall x\ \varphi(x, \mathbf{f}(x))$ belong to the so called Σ_1^1 –fragment of II order logic i.e. the class of prenex formulas in which the only second order quantifiers are existential quantifiers. This is the same class to which Ramsey sentences belong[7]. Anyway up to this point Hintikka's emphasis on the Skolem function as the true meaning of quantification does not seem to motivate completely the shift to a different logical framework. After all, the equivalence given by (I) is just ordinary logic.

Reflecting a little more on our game setting can help to address this worry. The "cat-feeding in the shade of Colosseum" situation can be seen as the kind of strategic interaction that game theory calls game with perfect information. What matters for our point here is that this means that at every point where each agent's strategy tells him to make a move, he knows everything that has happened in the game up to that point. Above, we identified the players of our game via the two

[7]See for a thorough discussion of the Ramsey eliminability issue, Benthem (1977).

quantifiers. Thus some mutual relation between the quantifiers should encode this characteristic of the game. The relation we are talking about is, of course, that of linear dependence. A quantifier Q_1 is linearly dependent on quantifier Q_2 iff the value of the variable quantified by Q_1 is dependent on the value of the variable quantified by Q_2.In ordinary first-order logic, the dependence is expressed via the scope of the quantifiers: Q_1 is dependent on Q_2 if Q_1 lies within the scope of Q_2.

Thus, to say that the value of the variables over which ∃ is ranging depends on the values of the variables over which ∀ is ranging, amounts to saying that the move made by ∃ at each point of the game takes always into account the move made by ∀ at that point .

Now, we are interested in the games in which the actions prescribed to a player by his strategy are taken without knowing the moves of the opponent – in game-theoretic terms these are games with *imperfect* information. To maintain the symmetry with the preceding case our logic should be able to encode this element via some relation between the quantifiers. Such situations in fact can be represented by Skolem normal forms of the following type

$$\exists f \exists g \forall x \forall z\, \varphi(x, f(x), z, g(z)) \quad \text{(II), with g only depending on z.}$$ [8]

Thus even in this case we expect some form of quantification is instantiating a choice function[9]. But the pattern of quantification presented here is not first order. This is precisely because of the linear dependence that does not allow us to represent the simple fact that the value of a quantified variable vary independently from the values assumed by another variable. The type of Σ_1^1-sentences to which (II) belongs are equivalent to the prenex form:

$$\begin{matrix} \forall x \exists y \\ \forall z \exists u \end{matrix}\; \varphi(x, y, z, u) \qquad \text{(III)}$$

[8] See Johan Van Benthem and Kees Doets "Higher-order logic" pp 208-216 in Gabbay &Guentner (2001)
[9] Henkin's work shows that this is the case. cf Henkin,(1959).

where the peculiar pattern of quantification preceding the formula is known as an Henkin quantifier, and a proof has been provided[10] that every Σ_1^1- fragment of second order logic is equivalent to first order formulas preceded by an Henkin quantifier.

The sentence (III) presents a pattern of branching quantifiers that precisely express the idea that the occurrences of the variable u does not depend on the values assumed by x but only on the ones assumed by z. Now, since the link between quantification and Skolem functions appears in a broader context, Hintikka 's worries should appear more clearly. The instantiation of a choice function is linked with the interaction of quantifiers which goes beyond the scope of ordinary first order logic. The quest for a shift in our logical paradigms is grounded in that link . IF-logic is a framework equipped to represent contexts that can exhibit patterns analogous to games with imperfect information i.e. patterns of linear independence between the quantifiers. Thus, IF logic seems to be a more natural way to express quantified expressions and (III) can be translated in IF logic as follows:

$$(\forall x)(\forall z)(\exists y/\forall z)(\exists u/\forall x)\ \varphi(x, y, z, u)$$

With this as the motivation for the adoption of IF-logic as a general logical paradigm, Hintikka addresses structuralist worries by insisting that:

Such a logic does not enable us to say anything about particular matters of fact. It is good only for purely structural descriptions. It is in a sense the logic appropriate for the study of pure structures per se, devoid of all content.' (ibid., p. 298).

At this point the role that such a logical framework can play in the debate about Ramseyfication, and Structuralism depends upon the impact of the triviality argument on a Ramsey sentence

[10] See Enderton (1970).

expressed in IF logic. In Hintikka's terms the quantifier interaction still captures the models in which the empirical substructure of the theory is embeddable or in the case of the super-RS mentioned above, states that certain structures are instantiated at some not specified point in the world. Thus, such a translation could help the structural realist if within such a framework it could be shown that the ontological load of the predication is taken up by the quantifiers to the extent that somehow the quantifier interaction can cut down the number of models in which RS is true.
This point is crucial since Ketland's proof of the DF thesis (Ketland 2004) shows that Ramsey sentences precisely *do not constrain* the number of models in which the empirical substructures can be embedded. Assuming that Hintikka is correct in representing the role of T-terms as he does in 2., can a logic designed to express precisely the interactive character of quantification and its function-instantiating nature address this problem? Unfortunately, but not surprisingly, the answer is no. After all if a statement is trivial, lets say in Italian, we would not expect it to be interesting in its English translation!

Indeed, Hintikka himself contributed to this answer. In 1991 Gabriel Sandu proved that any Σ_1^1-sentence has an equivalent IF logic sentence, and Hintikka provided an analogous result in 1995[11]. That equivalence makes clear how any model theoretic problem holding in a standard version of RS is going to affect its IF logic-equivalent. After all, if they are equivalent they must be true in the same models and the problem is precisely that there are far too many models. Hintikka insists on the aptness of IF logic as a means of precisely formulating RS because he conceives the notion of structure in a purely formal way and consequently RS is devoid of any theoretical content.

The above analysis should have clarified that, despite Hintikka's line of argument, IF-logic can be detached from the purely formal notion of structure and from the consequent choice of formulating RS as theoretically contentless. In particular Independence Friendly Logic seems to allow the logical translation of sentences characterized by forms of quantification whose structure is inaccessible to the usual formal devices available in first- or second-order logic. Consider examples

[11] See Sandu (1991) and Hintikka (1995).

similar to those given above. In such cases, Independence Friendly Logic may appropriately translate the relevant theory. In this case we will effectively have a form of logical machinery that rightly mirrors the relations of quantification expressed in the original theory. This covers expressions that in the original theory already had the form of existential quantification. However, even if it is granted that the Ramsey sentence as formulated in Independence Friendly Logic can express more accurately these relations between quantified expressions, the trivialization cannot be avoided. Roughly speaking, we have a case of trivialization when, after replacing every T-term with existentially quantified variables, the structure of the theory becomes so broad that every domain of objects with the right cardinality can be a domain of realizers of the theory. In general Hintikka condemns himself to triviality because of his choice of conceiving of the structure in purely formal terms. This suggests that a plausible notion of structure is one that embodies some content, at least if such a structure has to be expressed in a Ramsey sentence.

3 Blocking the triviality with explicit definitions and multiple realisability: Carnapian themes in structuralism.

This section presents a further development of Ramseyfication due to Carnap and based on a sharp distinction between T-language and O-language. We explore both its explicitly structural character and the indeterminacy that seems to capture the essential characterisation of this idea of hidden natures within ESR. Finally we explore the nature of its ontological commitments.

Carnap rediscovered Ramseyfication through his attempt to extend Craig's Theorem to type theory[12]. His interests, as in the case of Ramsey and differently from Hintikka, had no relation with any structural realist view. His formulation was concerned with two closely entangled issues: the

[12] Psillos has dome more than anyone in bringing this work to the attention of present-day philosophers of science and a useful account can be found in (Psillos 2000)

definition of theoretical terms (T-terms) within the framework of the received view of theories; and that of a strategy to accommodate the change in scientific settings via a stable *partial framework*.

According to the Received View a theory can be seen as a formal axiom system T. An *extensional* interpretation for descriptive constants of the system is provided by relating them, *via* the so-called Correspondence Rules, to empirical reports expressed in a formal language L_O. The descriptive constants of L_O refer to observable items. The interpretation of T-statements can only be *partial* because of the issue of the meaning of T-terms. Defining the meaning of T- terms presents the following difficulty: the C-rules leave open the interpretation of these terms; they, simply, cannot be exhausted by connecting them even to a wide range of empirical data. This open status is an important feature of the development of the theoretical frames since it allows for further additions of C-rules and new data[13], but it seems to conspire against any attempt of definition. Furthermore, this open status is associated with an unobservable element that goes beyond the safe ground of sensorial experience.

Historically, in Carnap's agenda the definition of the T-terms features as an instance of the problem of establishing a criterion for analyticity[14]. Carnap's formulation leads to a structuralist treatment of the theoretical terms implying a form of multiple realizability. Furthermore, such a solution depends on a development of the Ramseyfication strategy that effectively neuters the Newman problem. Thus the relation to the problem of analyticity is relevant to a structuralist understanding of Carnap's position.

The distinction between analytical/synthetic statements in the theory amounts to distinguishing what the theory tells us about the phenomena from statements acting as meaning specifications. In a broad sense the meaning of the T-terms and T-statements is taken to be a

[13]See Carnap 1966, p. 267ff.

[14] The problem of analyticity and in particular the strategy adopted to solve it, had its genesis within Carnap's interest in the foundations of mathematics, although we shall not discuss this here (see Friedman, 1999).

function of the epistemic task of explaining and/or predicting the observational data[15]. Since they specify descriptive constants, mathematical and logical features and their mutual relations, T-postulates express the fundamental laws that the theory introduces. Given this characterization it is now clear in what sense a problem arises with regard to the meaning of these T-terms. They feature in T-postulates as descriptive constants but it is not clear what they describe since they do not refer to anything directly observable and there is no way to treat them as pure *façon de parlé* since there is no viable reduction of them to descriptions of fundamental sense data in the O language.[16]. The problem turns out to be that of isolating postulates expressing "truths in virtue of meaning" in a context in which the meaning of the relevant terms involved are only partially specified. On the other hand assimilating the issue of defining T-statements to that of analyticity corresponds to treating T-truth as truth essentially non-committed to any state of affairs. The theoretical terms form a web of meaning relations that constitutes the epistemic architecture of our theories. More accurately once it is clear that a definition is not viable except in some implicit way, the problem of analyticity becomes a problem of the definition of role occupancy. In other words, it is the problem of what occupies which position in a certain place of the web of meaning substantiating the epistemic purposes of the theory.

Carnap himself presented analyticity in broadly structural terms:

"To recognize analytic statements in a theoretical language, it is necessary to have A-postulates [*Analytical postulates*] that specify the *meaning relations holding among* the theoretical terms."[17]

To clarify what Carnap had in mind, from an historical perspective, defining the boundaries of the analytical truth of the language of a given theory corresponds to defining the syntactic structure of

[15] Carnap 1956, p 38: "[the] exact conditions which terms and sentences of the theoretical language must fulfil in order to have a positive function for the explanation and prediction of observable events and thus to be acceptable as empirically meaningful."
[16] Carnap observes that this irreducibility is particularly "evident from the fact that with their help, along with sentences regarding observable processes, predictions can be derived of future observable processes" See Carnap 1958, p 82.
[17] Carnap 1966, p. 267 italics ours.

the language itself. In this sense at the more fundamental level we find the logical and mathematical truths, whose analyticity depends on the way in which the logical and mathematical symbols are combined[18]. The T-postulates express truths which are analytical in the different sense of not depending upon matters of fact. In this sense such truths act as meaning specifications telling us the epistemic role played with respect to observable information by T-terms[19].

Let us now come to Carnap's solution to the problem of analyticity. According to the distinction introduced above, the theory in its usual formulation is translated into a non-interpreted axiom system T, expressed in a formal language L_T ; this language is based on a suitably rich logical, mathematical and descriptive vocabulary. The *partial* interpretation of this calculus relies on a set of C-rules that is designed to assign to the descriptive terms of T a factual content expressed in the observational language L_O. For the present purpose, L_O is assumed to be an *extended* observational language; where *extended* means that the language contains together with the descriptive O-constants, the entire vocabulary of mathematics and high order logic or set-theory[20] and not only the usual first order logic.

At this point, taking the conjunction of both sets of postulates, the translation can be presented as follows:

$$TC(t_1, \ldots t_n ; o_1, \ldots o_m)$$

where the $t_1, \ldots, t_n$ generically represent T-terms and $o_1, \ldots o_m$ O- terms.

The Ramsey sentence is built up from this translation in a two-step move:

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18 Friedman (1999) chp 7/8 emphasizes Carnap's debt to Wittgenstein's Tractatus for this combinatorial notion of logical truth and the changes that Carnap imposed to that general conception.

19 Hempel and Quine criticised the distinction between analytic and synthetic as arbitrary since the entire setting of a language changes under the pressure of "recalcitrant observations". As Psillos noticed this criticism leaves untouched Carnap's distinction since in his account the analytical truths are not conceived as truths invariant through linguistic change. It is worth emphasizing that in Carnap's account, the synthetic/analytic distinction is drawn *inside* the language of one theory. If a radical change is required in the T-postulates and in the C-rules to account for new empirical data, then the analytical truths can change too. Thus, what counts as an analytical truth is not necessarily invariant under radical changes in language. Cf. Psillos 2000, p.155

20 Carnap observes that this extension can be disputed because of the requirements L_O has to satisfy in order to be fully interpreted and thus completely meaningful .See Psillos 2000, p159 . These requirements are summarized in Carnap [(1956) p 41] , the criteria "touched" by the extension are constructivism and finitism, even if the latter is anyway satisfied at least in its weaker version i.e. L_O has at least one finite model.

a) the occurrences of all the T predicates and relations is replaced with appropriate second order variables, $u_1, \ldots u_n$;
b) the resulting sentence is bounded by existential quantifiers ranging over these variables;

$$^{R}TC: (\exists u_1), \ldots (\exists u_n) TC(u_1, \ldots u_n ; o_1, \ldots o_m)$$

The sentence so obtained is formulated in the observational language, or, to be accurate, in the above mentioned *extended* observational language, which is "observational" because the only descriptive constants it contains are the observational ones. As Carnap emphasizes "the Ramsey sentence has the same *explanatory and predictive power* as the original system of postulates"[21]. The existential generalization preserves the epistemic virtues of the original theory: insofar as the factual content is considered, and the two formulations are *empirically* equivalent: it can be proved that every empirical consequence of TC is an empirical consequence of ^{R}TC[22].

The Ramsey sentence introduced in this way is subject to trivialization exactly as in the preceding cases of Ramsey and Hintikka but crucially, given Carnap's solution of the problem of analyticity this is now a *virtue* since it grants that the only relevant content of the claim is the merely observable[23]. This in turn allows us to identify the synthetic content of the theory: the Ramsey sentence represents the synthetic content in the O-language.

Let P represent the factual content, let A_T be the meaning postulates for the theoretical language and A_O the meaning postulates for the observational language. A_O contains only analytic truths because in the case of the descriptive O-constants, the distinction analytic/synthetic follows

[21] Carnap 1966, p 252.
[22] Let S be any sentence that does not contain theoretical terms. Then,
$\vdash \exists u\, \Phi(u, o) \Rightarrow S \Leftrightarrow \vdash \neg S \Rightarrow \neg \exists u\, \Phi(u, o) \;\; \vdash \neg S \Rightarrow \forall u\, \neg\Phi(u, o) \Leftrightarrow \vdash \forall u\, (\neg S \Rightarrow \neg\Phi(u, o)) \Leftrightarrow$
$\vdash \forall u\, \Phi(u, o) \Rightarrow S \Leftrightarrow \vdash \Phi(t, o) \Rightarrow S$.
[23] Of course, this is of little comfort to the realist!

from the fact that analytic statements can be introduced as meaning postulates on the grounds that the interpretation of L_O is full[24].

Carnap's claim is that A_T can be expressed by the following conditional $^{R}TC \Rightarrow TC$, where P is captured by ^{R}TC. We shall prove in a moment that in this way $P\&A_T$ is logically equivalent to TC[25] but let us analyse Carnap's proposal. Certainly $^{R}TC \Rightarrow TC$ is not a *logical truth*, since ^{R}TC is an existential generalization of TC and therefore there are models of ^{R}TC in which TC is not true and thus the implication is not true. Instead, the implication $^{R}TC \Rightarrow TC$ it is a good candidate for a rigorous expression of the notion of analytical truth as truth in virtue of meaning or truth independent from any matter of fact since assuming the original theory is true the implication is true and there is no need for any verification. This has in our view another interesting implication. The triviality argument concerns Carnap's formulation of ^{R}TC but not the further development based on it. In fact the postulate A_T limits to all and only the models of the original theory the number of models in which $P\&A_T$ is true[26].

This characterization does the same job as the theory did, from the epistemic point of view, but at the cost of a holistic definition of the T-terms. This holism makes it impossible to pick out a specific term and analyse its meaning in the theory without taking the whole $P \& A_T$ into consideration. Carnap's regarded this as an inconvenience:

"… temperature in the old language was perhaps t_8 , let's say, just the 8th theoretical term. It has disappeared now: we are in L_O'. But there we have a variable u_8, which takes its place. But in order to use it […] we have to write all the n, let's say 20, existential quantifiers, all the theoretical postulates, all the correspondence postulates[…] Because if you were merely to write u_8 of such and such coordinates that would not even be a sentence, because there is a free variable in it; it would not mean anything. And it would not help to just add the one quantifier because that does not tell you that it is temperature. *The*

[24]See in particular Carnap, R., Meaning Postulates, printed as appendix in Carnap, R.,(1956b) pp 222-229.
[25] Carnap SBL in Psillos, S.,(1999b).
[26] See Winnie (1971) pp. 291-293.

essential characteristics {of temperature} come from the combinations and connections with other theoretical terms {which} are expressed in the T-postulates, and the combinations and connections with observations terms, {which are} expressed in the C-postulates."[27]

This was an inconvenience that could be turned around only by means of some sort of explicit definition. Providing the logical tool for such an explicit definition is the motivation behind Carnap's adoption of Hilbert's ε-operator[28].

This operator is a choice function: provided that the given class to which it is applied is not empty, the operator picks out an element of the class, precisely a *representative* of the class:[29]

(1) $\exists(y)Fy \Rightarrow F(\varepsilon_x Fx)$

(2) $\forall(Fx \Leftrightarrow Gx) \Rightarrow \varepsilon_x Fx = \varepsilon_x Gx$

The first axiom states that if something exists that satisfies the open formula Fx, where x is the only variable occurring free, then $\varepsilon_x Fx$ is the ε-term that denotes an object that satisfies Fx. This object represents the formula or the set of objects corresponding to the formula. The second axiom states a form of extensionality for the operator claiming that if two formulas are equivalent, they have the same representative. Notice that if some x bears the property specified by F, the function chooses one of the members of the class captured by F but it does not specify how many elements there are in the class or which of these has been chosen.

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[27] Carnap, R., SBL in Psillos (1999b), pp. 167-8. italics mine.

[28] It has to be emphasized that given the quest for an explicit definition, the answer in Carnap's approach has to be possible with the resources of logic and mathematics alone in the framework of the extended observation language. The choice for the use of the ε-operator is not the choice for a completely neutral logical device, because of the conceptual relation between this operator and the axiom of choice. Nevertheless it yielded the searched for definition with just the resources of a very powerful logic –the whole of set theory and mathematics- and in the observation language. Thus Carnap has performed his task meeting the requirements for the treatment of the theoretical terms he himself fixed in the "Methodological Character of the Theoretical Terms" and nevertheless providing a characterization of the notion of analyticity.

[29] See Carnap 1961, in particular pp.157/8.

It is worth stressing the indeterminate character of the choice performed by this operator since this aspect is now crucial to Carnap's explicit definition of T-terms. The preceding formulation of the theory was A_T & P. A_T will be now replaced by n postulates of the form A^i_T , each of which is supposed to define explicitly each t term of the n-tuple ($t_1, \ldots t_n$):

Let $u_1,\ldots,u_n$ be variables for T-terms. If $\mathbf{t} = < t_1, \ldots, t_n >$, $\mathbf{u} = < u_1,\ldots,u_n >$ and $\mathbf{o} = < o_1,\ldots, o_1>$ then we have TC(**t, o**) for the old theory; $^R TC = \exists \mathbf{u}\ TC(\mathbf{u}, \mathbf{o})$ and $A_T = \exists \mathbf{u}\ TC(\mathbf{u}, \mathbf{o}) \Rightarrow TC(\mathbf{t}, \mathbf{o})$. A_T can be read as claiming "*if there is anything that bears the relation Φ [≡TC] to **o**, then **t** does so*"[30]. Now this claim can be expressed explicitly applying the first ε-axiom to $^R TC$:

(5) $$A^0_T : \mathbf{t} = \varepsilon_{\mathbf{u}}\ TC(\mathbf{u}, \mathbf{o})$$

Since $\mathbf{t} = < t_1, \ldots, t_n>$, from (5) we can derive a schema to create definitions for each of the members of the n-tuple $t_1, \ldots, t_n$:

(6) $$A^i_T : \ \mathbf{t}_i = \varepsilon_x\ [(\exists u_1)\ldots(\exists u_n)(t = <u_1\ldots u_n> \bullet x = u_i)]$$

Carnap showed[31] that it is possible to derive A_T from A^0_T and A^i_T thus the new formulation of the theory is perfectly equivalent to the preceding one and via A_T to TC and it allows an explicit definition of all the t-terms occurring in TC completely in an extended observational ε-language. Let us now turn to the nature of these explicit definitions. As we have noticed above the ε operator provide an indeterminate choice over a class that can contain more than one element to be satisfied. In other words, in the class of entities captured by the theory, in (5) say, there can be several items satisfying the theory: the theory *is multiply realizable*.

[30] Carnap 1961, p 161, italics ours.
[31] See Carnap 1961, p 162.

An initial consequence of this situation is that if further empirical information has to be added it can be accommodated within the same framework. Thus the development which the theory undergoes can easily be absorbed:

"[…] this indeterminacy is just the one which we need for the theoretical concepts, if we use this explicit definition, which I used in my definition of **t**, because I defined **t** as the selection object which has the relation TC to **o** […] we do not want to give more because the meaning should be left unspecified in some respect, because otherwise the physicist could not – has he wants to – add tomorrow more and more postulates, and even more and more correspondence postulates, thereby make the meaning of the same term more specific than {it is} today"[32]

Here, the key role is played by the idea of capturing a class of items all satisfying the theory; roughly speaking we can say that further specification introduced to accommodate new empirical evidence will refine the characterization within the same class. Theory-change is thus accounted for via *multiple realizability*. The class of realizers is conceived in extensional terms. Now, the question arises, what kind of commitment[33] is partially specified by the multiply realizable n-tuple of terms defined *via* this procedure? In other terms does this multiple realizability allow a realist account of the hidden natures? We shall now argue that it doesn't.

Carnap's account equates the original theory TC to ^{R}TC & (^{R}TC $\Rightarrow$ TC). Hence, the explicit definition of T-terms via the ε-operator is constructed out of a class of analytical truths. All we know about the realizers is true but has nothing to do with any matter of fact. The structure of the

[32] Carnap, R., SBL , in Psillos 1999b, p. 171.

[33] The focus being on the logical type to which theoretical notions belong, we can take terms to range over mathematical objects. Carnap states that there is no further commitment to the existence of something to which such functions should correspond or to the existence of the functions themselves. We can take theoretical terms as denoting mathematical functions. Physical magnitudes like, for instance, "[mass-density] maybe introduced, which have a value for every space-time point e.g. a real number. A function of this sort can be construed in our system by a function *F* of quadruples of real numbers. *Here again, F is identical with a mathematical function of the same logical type […] it is not necessary to assume new sorts of objects for the descriptive T-terms of theoretical physics*. These terms designate mathematical objects, for example numbers or function of numbers or the like which, however, are physically characterized, namely, so they have the relations to the observable processes established by the C-postulates while simultaneously satisfying the conditions given in the T-postulates" On this basis Psillos claims that Carnap's idea corresponds to an *ante litteram* form of ESR.

theory does not express any truth going beyond what is empirically true in the models in which the original theory is true. The only structural characterization is completely logical-syntactical in nature. Theoretical knowledge plays the role of expressing the boundaries – the structure in this sense – of the specific language we are employing to fulfil our epistemic purposes. Thus any issue of ontological commitment makes sense only from an internalist point of view, i.e. in terms of the acceptance of a framework. The structural component is therefore purely syntactical and completely framework-dependent.

This is surely not what the epistemic structural realist wants. We recall that on this view what we know, and what we should be realists about, are certain physical structures, represented (for Worrall at least) by certain equations in our theories, which are underpinned by epistemically 'hidden' natures. These structures are supposed to be a feature of reality that goes beyond the merely empirical, else structural realism will collapse into some form of (structural) empricism, as advocated by van Fraassen for example, But if the 'hiddenness' of the natures is represented in a Carnapian manner, through the use of the Hilbert operator, the attendant notion of structure appears to be entirely too 'thin' for realist purposes. On this view, we are not pointing to some structural element of reality to which the T-terms refer; rather, in adopting Carnap's strategy we describe merely the syntactic structure of the language of the theory. This is indeed a structuralist approach but certainly not a realist one.

Section II -Realism without structuralism

1. Multiple realizability, functional definitions and the Humility thesis.

Lewis also famously deployed Ramseyfication, but this time to realist ends. In the following we compare his use of this technique in two different contexts to emphasize how multiple realizability, as he understood it, can represent a feature leading to a realist view of theories, but one that is not appropriately structural in the sense demanded by ESR.

2.1 A functional definition of T-terms and the early rejection of Mutiple realizability.

Perhaps the most important discussion of Ramseyfication in the modern context, drawn upon by almost all recent commentators, is that due to Lewis (Lewis,1970). In Lewis's view the theoretical-empirical distinction is to be rejected. The language of T is understood in natural terms as any other kind of language. The definition of T-terms is formulated via O-terms that in this case are terms whose meaning is acquired in scientific practice and thus is non-problematic[34]. The language is assumed to be made of names under the assumption that it provides enough copulas, thus instead of a predication as "F(_)", we can have "__ has F-hood." The language is further endowed with nonextensional operators and connectives so in its O-vocabulary there are terms like "__because__" or "__is a law that__" . Since we are dealing with scientific theories we assume that if any T-term is denotationless the theory is false. Nevertheless, the system of logic chosen to formulate the Ramsey sentence (namely, Scott's denotationless term tolerant logic) is designed to deal with denotationless terms.[35]

Lewis's Ramsey sentence is designed even for intensional predication and is therefore very different in term of content from Carnap's. Lewis is after a definition of T-terms in a more or less straightforwardly realist fashion, therefore for him multiple realization is not a desirable feature. Here is how he characterizes the formal machinery:

[34] There is a concern one might have with Lewis's translation strategy. The equivalence of 'old' terms with 'well understood' and 'new' with 'problematic' is not straightforward. In particular this dichotomy does not take into account the role played by mixed predicates and relations in securing the empirical equivalence of the Ramsey sentence with the original theory. Our new language is very likely to contain problematic terms applicable at both the observable and the non observable level. If we replace them with variables some empirical content will be lost, but if we don't the choice has to be justified on different grounds otherwise we are retaining within our sentence some problematic term .
[35] See Lewis 1970.

(1) $\exists y_1, \ldots, y_n \forall x_1,\ldots,x_n (T[x_1\ldots x_n] \equiv . y_1 = x_1 \& \ldots \& y_n = x_n) \Rightarrow T[\tau_1\ldots\tau_n]$

(1) states that if T is uniquely realized then it is realized by the items named by $\tau_1\ldots\tau_n$ and, as Lewis notices, it is logically implied from the Carnap sentence of the theory

(2) $\neg \exists x_1,\ldots,x_n (T[x_1\ldots x_n]) \Rightarrow . \neg \exists x (x = \tau_1) \& \ldots \& \neg \exists (x = \tau_n)$

(2) states that if T is not realized, then $\tau_1\ldots\tau_n$ names nothing, it is not a consequence of the Carnap sentence.

(3) $\exists x_1,\ldots,x_n T[x_1\ldots x_n] \& \neg \exists y_1, \ldots, y_n \forall x_1,\ldots,x_n (T[x_1\ldots x_n] \equiv . y_1 = x_1 \& \ldots \& y_n = x_n).$

$\Rightarrow \neg \exists x (x = \tau_1) \& \ldots \& \neg \exists (x = \tau_n)$

(3) states that if T is multiply realized then $\tau_1\ldots\tau_n$ do not name anything.

As specified above Lewis had to add a postulate stating that if the Ramsey Sentence is multiply realized then it is false. Even with the introduction of intensional content the Ramsey sentence still maintains that character of indeterminacy.

Let us explore Lewis's concern with multiple realizability. A 'realization' of a theory T is simply a n-tuple of entities denoted by the theoretical terms of T and which satisfies the relevant 'realization formula' of T (obtained by replacing the theoretical terms by variables). Carnap allows for the case in which T is multiply realized and according to the associated Carnap sentence, the theoretical terms name the components of some realization or other. Lewis insists that this concedes too much to the instrumentalist view. Thus he demands that the theoretical terms of a multiply realized theory be denotationless. The idea is this: if the theory is uniquely realised, then the Carnap sentence does the job, in that it states that the T-terms name the entities in the *n*-tuple that constitutes this unique realisation. If the theory is not realised – as in the case of phlogiston theory, for example – then the Carnap sentence actually says nothing about the denotation of the T-terms. But as Lewis suggests, it seems reasonable to demand that in such cases the T-terms do not name anything. (There is the complication of possible near-realisations, in the sense of an *n*-tuple that realises some theory obtained from the original one by some comparatively minor tweaking. In that case we take the weaker theory of which the n-tuples is the (unique) realisation and take that as the real term-introducing theory (*ibid.*, p. 432).) Finally there is the case of possible multiple realisations, where there is more than one *n*-tuple realising the theory. In such cases, according to the Carnap sentence the T-terms name the components of one of these realisations but don't say which. To insist that the terms do not name anything or that they arbitrarily name the components of one of the realisations concedes too much to instrumentalism and furthermore, Lewis argues, scientists themselves appear to proceed with the expectation that their theories will be uniquely realised. Hence he concludes that in such cases the T-terms must be take to be denotationless and theoretical postulates containing such terms will then be false. It is this which motivates the use of Scott's denotationless term tolerant logic as the underlying formal framework and the prefacing of the relevant Ramsey sentences with the 'uniqueness' operator or ι–operator.

Does the possibility of multiple realizability really concede too much to the anti-realist? One might think multiple realizability (MR), construed epistemically, is reminiscent of the agnosticism underpinning van Fraassen's constructive empiricism (which, in the early criticisms at least, was often characterised as a form of instrumentalism). However, we should be careful here. Van Fraassen's agnosticism is closely tied to the thesis of underdetermination, and the underdetermination here is that of theories by evidence so it is not a case just of the *entities* being different but of the theoretical predicates also[36].

[36] This is true even of the case that van Fraassen draws on in *The Scientific Image*, of Newton vs. Leibniz, in which the crucial attribution of absolute velocity is the main focus. And of course even if unobservable, this theoretical predicate can be related to observable consequences in the bucket thought experiment.

But now this raises the following concern: if the kind of underdetermination van Fraassen deploys against the realist does not count as a form of MR, then what does?! Lewis writes of our intuitions in this matter, insisting that both us and scientists at least aim for unique realisation. The latter, in particular, helps suggest an ‘ its just a form of underdetermination’ reading, but we’ve just seen that that’s not appropriate and now we’re left wondering what these intuitions are supposed to be.

Perhaps we can explore the issue along the following lines: consider for simplicity the sentence (∃x) [T(x, O_1, O_2, … O_m)] (simplified for one new term only). In the case of multiple realisation, we will presumably have two 1-tuples which realize the open sentence 'T(x)'. Call these ‘electron’ and ‘smelectron’. In what sense can these actually be distinct, given that both realize 'T(x)' and, therefore, have the same properties? (Let’s assume that there are no other sentences expressing different properties that one of these realizers but not the other, realizes; that is that this sentence is a ‘final’ sentence in the appropriate sense.) The issue is, how are n-tuples to be distinguished if multiple realisation is to be a possibility in the case of scientific theories?

If both electron and smelectrons are supposed to satisfy T, then either T is only provisional and not final (as, we presume, most current theories are), in which case the difference in theoretical properties of electrons and smelectrons will be reflected in the replacement of T by its successor, satisfied by one or the other, or T is the final theory, in which case *prima facie* there should not be any theoretical difference. In the former case, MR appears to be merely a reflection of our epistemic fallibility and it is hard to see what we should be so agitated about. If, on the other hand, MR is to be understood not epistemically but ontologically, then how are we to make sense of it when all the theoretical properties of electrons and smelectrons are wrapped up in T? Can we really make sense of this notion of multiple realizability?

2 The Thesis of Humility

Interestingly enough, in one of the last papers he wrote (Lewis preprint), Lewis discusses again the issue of what we can know on the basis of our theories and his contribution seems precisely to address our last problem in a way that fulfils some of the *desiderata* laid down by advocates of ESR. The general context for the paper is Langton's analysis of Kant's transcendental philosophy as an investigation of the limits of our knowledge as a form of receptivity[37]. This analysis is grounded on a peculiar metaphysical thesis. Reality affects us perceptually and this affection is the ground of our knowledge. However, this affection is not due to the intrinsic properties of physical entities. On the contrary it depends on their relational properties. The genesis of the idea of a limitation in our capability to know reality is in Kant's disagreement with Leibniz regarding the relation between the intrinsic and relational properties of the entity. Whereas Leibniz took the latter to be reducible to the former, Kant thought they were irreducible. This allowed him to consider as non-influential the intrinsic properties of the entities with respect to their role in our knowledge and conclude that something is always "out of the picture".

In his paper, Lewis is after a defence of a form of the Humility thesis detached from the picture in which the relational properties are irreducible to the intrinsic ones. In his case what plays a decisive metaphysical role in expressing the sense of humility is a combinatorial principle applied to the properties of the entities concerned.

Here **T** is taken to be the final theory of science. The language of **T** is formulated following a strategy similar to his earlier work above but with a meaningful difference: T-terms label only fundamental properties (with the only exception of idlers and aliens properties whose consideration is not important here). We further assume that a fundamental property we refer to via a T-term always falls within a category containing at least two such properties.

Once our RS is formulated in the usual way, we have the following situation: the actual realization of **T** *prima facie* seems unique but the role-occupancy of the fundamental properties is specified by the RS which has the same empirical success as that of **T** and is multiply realized. This

[37] The role of Kantian views in the history of structuralism deserves further discussion. Worrall's notion of 'hidden' natures is taken directly from Poincaré who was heavily influenced by Kant, of course.

means that in the case that **T** could be proved to be multiply realizable there is no empirical evidence that can decide between the different possible realizations. With regard to this form of humility two factors are crucial:

a) **T** and its RS have the same empirical power thus RS can be taken to specify which role the fundamental properties have to play to account for all empirical data and this role is all we need for our epistemic purposes.
b) Since we assume that our fundamental properties belong to classes with at least two members, the combinatorial principle allows us to conclude that the same phenomena would be observable in worlds in which fundamental properties belonging to the same category are swapped. In other words there is room to argue that on this view, even the final **T** is multiply realizable.

The distinction between being the ground for a power and the power itself and the rejection of the reducibility of the latter to the former was the core of Kantian humility. What we will call with Lewis, *Ramseyan humility* is based on the possibility that our theories may be multiply realized. We can know that a role is occupied by a fundamental property and this is crucial in order to account for observable data, but we are not in the position to establish *which* property in a class of fundamental properties occupies it because the observable phenomena would remain the same whatever property in that class is chosen. The RS here plays the crucial role because its empirical equivalence with the original theory tells us precisely that once the role occupancy is granted the empirical outcome would be the same.

Let us now just touch on the metaphysical grounds for drawing this conclusion. The epistemic limitation depends upon a precise metaphysical picture: First of all, we have the assumption of combinatorialism: we can take apart the distinct elements of a possibility and rearrange them. Since there is no necessary connection between distinct existences, the result of such a combination will be another possibility. In general combinatorialism states that possibility is preserved under permutation of items and *entails that the laws of nature are contingent.*

Secondly, we have here a form of Quidditism, which is the view that *properties* have a kind of primitive identity across possible worlds (Black 2000). Thus, different possibilities can differ only on the permutation of fundamental properties. This offers a further way of understanding the 'hidden' natures of ESR. As Psillos, for example, has emphasised (Psillos 1999), the properties that feature in the theory's laws will be the relevant properties of the underlying entities (such as charge, mass, etc.), and hence, as French and Ladyman (2003) have argued, what remains 'hidden' will have to be something 'over and above' these properties, such as some form of haecceity. However, if we understand this 'hiddenness' via multiple realizability, as indicated here, we see that there is a further possibility according to which the epistemic structural realist's 'hidden natures' are cashed out in terms of the quiddities of the relevant properties. Not everyone would be happy with such a suggestion (see, for example, Bird forthcoming), but it strikes us as an interesting option to explore (although we shall not do so here).

Let us now summarise this second line of understanding the role of Ramseyfication. In his 1970 paper, Lewis took a particular realist stance which drove his rejection of (a form of) multiple realizability. Nonetheless, it is indisputable that the Ramsey sentence in Lewis's own version carries a highly theoretical load and the items featuring in the descriptions that the sentence provides are not only empirical or *observational*; the early worries of conceding too much to instrumentalism were thus too quick. Once rooted in multiple realizability the thesis of humility seems to have a strongly realist basis. Furthermore this thesis seems to ground the metaphysical principle of compositionality on the distinction among the elements of reality accessible to our knowledge and the ones that are not.

What about the consequences for epistemic structural realism once this perspective is embraced? First of all, Lewis repeatedly observes, the T-terms removed in this picture are a small number - as small as the number of the intrinsic properties, which in turns entails that this view admits in the Ramsey sentence a relevant amount of non-purely structural or relational knowledge although it frames it in a relational description, and this is true even in the version of the Ramsey sentence provided in the earlier paper. Secondly, the overall picture relies on combinatorialism which in turns pushes us to abandon a conception of laws of nature as involving necessary connections. This in turn means that any articulated set of relational properties captured by the structure of the theory also loses any character of necessity.

Now this may or may not be a heavy cost to bear, depending on one's attitude to laws and necessity of course. The epistemic structural realist could adopt some form of regularity view, although there might be concern as to how well this sits with a realist stance in general. Alternatively, she could opt for some form of dispositional essentialism, as Bird advocates (forthcoming). Whatever options she settles on, our claim here is simply that dropping necessity introduces a further pressure on her position.

Consider: the epistemic structural realist holds, as a central thesis, that structure is epistemically independent from the underlying, and hidden, 'natures'. Now, one can argue that this epistemic distinction must be based on some metaphysical distinction: putting it rather crudely, if structure can be known and 'natures' not, then there must be some difference in their metaphysical characteristics which underpins this. The source of the difference can lie with the 'natures' or the structures. One option, as indicated above, is to insist that what remains 'hidden' will be have to be something 'over and above' these properties. French and Ladyman (2003) have argued that this 'something' has to do with the entities' individuality, or lack thereof, and have drawn on the consequences of quantum physics for particle individuality to push for a shift away from epistemic structural realism and towards the ontic form. Alternatively, the epistemic structural realist could insist that it is with the nature of the structure that the distinction lies. And one way of articulating that would be on the basis of this structure embodying some form of necessary connection.

On the above Lewisian view, however, there is no necessary connection 'tying together' the set of properties represented in the laws. They just happen to come that way. And if we know the structure, then we know all there is to know about these properties and their interrelationships. But then the distinction between 'structure' and the 'nature' of the underlying entities appears to have become blurred and the emphasis now seems more on the idea of expressing rigorously some limitation on our access to reality. The suggestion, then, is that a cost of adopting the Lewisian picture would be increased pressure to locate the distinction between structure and nature with the latter and hence the necessity of facing up to French and Ladyman's arguments.

In general, then, within the above picture, multiple realizability can provide a rigorous way to define the idea of hidden natures but at the cost of admitting a great deal of non-relational content in the notion of structure, precisely the kind of content that caused the PMI-related problems. Further, the structuralist seems now forced to pay for the characterization of the hidden natures with the money of the necessity of the laws. Of course, she may feel that is a cost worth paying, but it is a cost to be aware of nevertheless.

3. Conclusion

To make sense of epistemic structural realism, it is not enough that the structural dimension be appropriately represented – the idea of there being 'hidden natures' underpinning this structure must also be captured. Here we have explored some formal ways of doing this but they leave the structural realist with a dilemma: following Carnap, we get a nice representation of the structural element, but we lose realism, following Lewis, we adhere to the realist perspective, but we lose a standard understanding of the laws that the epistemic structural realist sets such great store by. This is not to suggest that these are the only ways to conceptualise Worrall's 'hidden natures' but the epistemic structural realist has yet to come up with a viable alternative.

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